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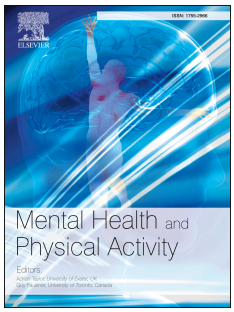

The Interactive Role of Exercise and Sleep on Veteran Recovery from Symptoms of PTSD

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The Interactive Role of Exercise and Sleep on Veteran Recovery from Symptoms of PTSD

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Abstract

Introduction. Posttraumatic Stress Disorder (PTSD) is prevalent among military veterans and is associated with a number of negative outcomes. Despite available treatments, rates of recovery are poor and many symptoms persist post-treatment. Previous research suggests that exercise functions to reduce symptoms of anxiety and improve sleep quality, though its effects are understudied among those with PTSD.

Method. We sought to assess the extent to which exercise and sleep interactively impact changes in PTSD severity. Participants were 217 veterans in residential PTSD treatment who were offered the opportunity to participate in a bike-exercise program. Data were collected at treatment intake and discharge.

Results. Exercise (defined as total volume of cycling completed over the course of treatment) was associated with greater reductions in PTSD hyperarousal symptoms at discharge only among veterans with poor intake sleep quality.

Conclusions. Overall, exercise may be a beneficial adjunctive treatment for reducing hyperarousal symptoms among individuals with PTSD and poor sleep.

Keywords: PTSD, veterans, physical, exercise, sleep, hyperarousal

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Abstract

Posttraumatic Stress Disorder (PTSD) is highly prevalent among military veterans and is associated with a number of negative outcomes. Despite available treatments, rates of recovery are poor and many symptoms persist post-treatment. Previous research suggests that exercise functions to reduce symptoms of anxiety and improve sleep quality, though its effects are understudied among those with PTSD. We sought to assess the extent to which exercise and sleep interactively impact changes in PTSD severity. Participants were 217 veterans in residential PTSD treatment who were offered the opportunity to participate in a bicycling program. Data were collected at treatment intake and discharge. Exercise (defined as total miles cycled over the course of treatment) was associated with greater reductions in PTSD hyperarousal symptoms at discharge only among veterans with poor intake sleep quality. Overall, exercise may be a beneficial adjunctive treatment for reducing hyperarousal symptoms among individuals with PTSD and poor sleep.

Keywords: PTSD, veterans, physical, exercise, sleep, hyperarousal

The Interactive Role of Exercise and Sleep on Veteran Recovery from Symptoms of PTSD

Posttraumatic stress disorder (PTSD) is characterized by an inability to recover from a stress reaction following exposure to a traumatic event (Kessler, Sonnega, Bromet, Hughes, & Nelson, 1995) and is defined as the non-remittance of symptoms by 1-month post-traumatic event exposure (DSM-5; APA, 2013). Military personnel are among the most at-risk populations for exposure to traumatic events and subsequent onset of PTSD (Schlender, Caddell, Ebert, et al., 2002). The percentage of veterans served by the Veterans Health Administration (VHA) and diagnosed with PTSD increased by 60% between 2001 and 2007 (VHA, 2009). Such trends are concerning given that PTSD is associated with a number of negative consequences including frequent comorbid psychiatric disorders (Kessler, 2000), physical health problems (Green & Kimerling, 2004), and functional impairment (e.g., marital difficulties, unemployment; Kessler, 2000). Although effective interventions are available for PTSD (e.g., cognitive processing therapy and prolonged exposure; Foa, Dancu, Hembree, Jaycox, Meadows, & Street, 1999; Resick, Monson, & Chard, 2007), they are time-intensive, require trained specialized clinicians, and residual symptoms of PTSD often persist following successful treatment completion (Zayfert & DeViva, 2004). Accordingly, identification of low-cost, non-specialized adjunctive interventions may allow providers to reach more individuals and further optimize treatment outcomes. Exercise is one such intervention that holds both empirical and theoretical promise.

A wealth of research has demonstrated that engagement in mild to moderate levels of exercise (e.g., a brisk walk of at least 30 minutes, multiple times weekly) is an effective independent and adjunctive intervention for psychological disorders. Indeed, meta-analyses collectively indicate that physical activity is associated with reductions in anxiety among both clinical and non-clinical populations (Petruzzello, Jones, & Tate, 1997; Wipfli, Rethorst, &

Landers, 2008) and can yield effects (i.e., affective symptom reduction) equivalent to those observed with cognitive behavioral therapy for anxiety and depression (For a review see Zschucke, Gaudlitz, & Strohle, 2013).

Evidence has also consistently highlighted the benefits of exercise among individuals who suffer from poor sleep. Moderate intensity aerobic exercise has been associated with reduced polysomnographic measured: sleep onset latency, total wake time, number of awakenings, and amount of time spent in stage 1 sleep, while increasing total sleep time, sleep efficiency, and amount of time in stage 2 sleep (Passos, Poyares, Santana, Garbuio, Tufik, & Mello, 2010; King, Pruitt, Woo, et al., 2008). Moderate intensity exercise has also been shown to improve self-reported indices of sleep, including sleep quality, sleep latency, sleep duration, daytime dysfunction, and sleep efficiency (King Oman, Brassington, Bliwise, & Haskell, 1997; Reid, Baron, Lu, Naylor, Wolfe, & Zee, 2010; Singh, Clements, & Fiatarone, 1997).

Taken together, these studies suggest that individuals with anxiety and co-occurring sleep problems may experience the greatest benefits from exercise (Asmundson, Fetzner, DeBoer, Powers, Otto, & Smits, 2013; Brand, Gerber, Beck, Hatzinger, Puhse, Holsboer-Trachsler, 2010). While the mechanisms underlying these relations are still being investigated, initial work suggests that exercise may have a positive impact on sleep and anxiety through improvement in physical fitness and habituation to somatic arousal (Salmon et al., 2001; Tworoger et al., 2003).

Although the benefits of exercise on anxiety, depression, and sleep are well documented, less is known about its impact on PTSD symptoms. Preliminary data, based on small non-controlled studies, have suggested positive benefits of including exercise within PTSD interventions (See Zschucke, Gaudlitz, & Strohle, 2013). Moreover, exercise holds theoretical promise for addressing symptoms of PTSD among those with particularly poor sleep. Sleep

problems represent the primary presenting concern among individuals with PTSD, with 74-90% of currently deployed and post-deployed veterans reporting significant symptoms of insomnia (Lewis, Craemer, & Failla, 2009), which have in turn been associated with greater PTSD symptom severity (Krakow, Germain, Warner, Schrader, Koss, & Hollifield, 2001). Based on this co-occurrence, the positive impact of exercise on PTSD symptoms may be particularly salient for those with poor sleep.

The present study sought to examine the hypothesis that exercise (defined as total miles cycled over the course of treatment) would be associated with lower PTSD symptom severity at treatment discharge, particularly among those with poor baseline (treatment intake) sleep quality, after accounting for age, baseline (treatment intake) PTSD symptom severity, treatment changes in depression symptoms, and total number of days cycled. As the current study included Vietnam-era as well as OEF/OIF veterans, age was included as a covariate due to its association with sleep quality (Buysse, Monk, & Begley, 2005).

Method

Participants

Participants were 217 male military veterans (M_{age} = 52.18 years, *SD* = 7.06; Range 24-70 years) admitted to a 60-90-day VA residential rehabilitation program for PTSD, during which time individuals participated in cognitive behavioral therapy (CBT) for PTSD. Exclusion criteria for enrollment in the program included: (a) illicit substance and/or alcohol use during treatment, and (b) medical conditions with high probabilities of significantly interfering with or preventing psychological treatment (i.e., those unable to move about independently). The racial/ethnic composition of the sample was as follows: 60.9% Caucasian, 17.9% African American, 11.3% Hispanic/Latino, 3.3% Native American, 2.0% Pacific Islander, 0.7% Asian, and 4.0% identified

as "other." In terms of psychiatric comorbidities, 92.2% of the sample had a co-occurring mood disorder, 76.0% reported a history of at least one substance use disorder (patients were required to abstain from substance use), and 14.0% had a co-occurring anxiety disorder. Per treatment facility regulations at the time of the study, all patients admitted to treatment were required to be abstinent from all substances (except caffeine and nicotine) for at least 2 weeks prior to treatment intake. Abstinence was confirmed via urine toxicology screen at intake and weekly throughout the duration of treatment.

Measures

Pittsburgh Sleep Quality Index (PSQI; Buysse, Reynolds, Monk, & Berman, 1989). The PSQI is a 19-item questionnaire that provides an index of global sleep quality and seven components of sleep quality. Respondents (a) answer open-ended questions in which responses are coded based on established categories and (b) indicate answers on a 4-point Likert-type scale (0 = *very good* to 3 = *very bad*). In the current study the PSQI total score (sum of all 7 components) was used. Cronbach's α = .51 for the current sample. A total score on the PSQI greater than 5 is indicative of clinical levels of insomnia (Buysse et al., 1989).

PTSD Checklist – Military Version (PCL-M; Weathers, Litz, Herman, Huska, & Keane, 1993). The 17-item PCL-M was used to index PTSD symptom severity. The PCL-M yields three symptom clusters (re-experiencing, avoidance/numbing, and hyperarousal) as well as a total score indicative of PTSD symptom severity. To account for conceptual overlap with our measure of sleep quality, the sleep item was removed prior to scoring. Cronbach's α's = Intake (re-experiencing = .87, avoidance = .75, hyperarousal = .76); Discharge (re-experiencing = .88, avoidance = .87, hyperarousal = .87) for the current sample.

Beck Depression Inventory –II (BDI-II; Beck, Steer, & Brown, 1996) is a 21-item self-report measure of depression symptoms. The sleep item was removed prior to calculation of a total score. Cronbach's α = .87 (intake) and .93 (discharge) in the current sample.

Exercise. Distance cycled while engaged in a group bicycling program was used to index exercise. Interested veterans voluntarily participated in group bicycling outings led and supervised by a staff trainer. Veterans were provided access to a road bike outfitted with a cyclometer to measure total miles cycled per cycling event. Daily mileage was recorded. Upon discharge, the total number of days and miles cycled over the course of treatment was then calculated. This resulted in a continuous index of total mileage cycled over the course of treatment. In addition to the continuous index, exercise was trichotomized to generate groups as research has shown that varying levels of exercise have significantly different impact on mood (Arent, Landers, & Etnier, 2000). Examination of a histogram did not yield a natural cut-point. Therefore, an empirical method was necessary to determine where to split the groups. For this reason a median split was employed. This resulted in a non-cycling group (n = 176), those who cycled between 1 and 59.5 miles (moderate mileage cycled; n = 20), and those who cycled 59.6 miles or more (high mileage cycled; n = 21).

Procedure

Demographic characteristics and the PSQI were obtained at intake; the BDI-II and PCL were administered at intake and discharge. Adjunct cycling occurred simultaneously to cognitive behavioral therapy. For this reason, cycling data were collected throughout treatment.

Analytic Method

Prior to the main analyses, we conducted t-tests to determine whether study variables differed between those who cycled and those who chose not to engage in the cycling program.

Next, zero order correlations were examined among continuous variables. Hypotheses were then tested using four Hierarchical Multiple Regression (HMR) analyses (one for PTSD total and one for each symptom cluster), with all continuous variables standardized prior to entry (Cohen, Cohen, West, & Aiken, 2003). In Step 1, main effects for exercise and sleep quality were entered simultaneously, with the interaction of exercise and sleep quality entered in Step 2. Finally, age, intake PTSD symptom severity, treatment change in depression symptoms, and total number of days cycled were entered into Step 3 as covariates. Depression symptoms were included as a covariate so as to determine the unique role of exercise on PTSD beyond the relation already established for depression (Cooney, Dwan, Greig, et al., 2013). Age was included as a covariate due to the large age range and the impact of age on sleep (Buysse et al., 2005). The total number of days cycled was included as a covariate in order to account for differences in the number of individual opportunities to cycle. Covariates were entered in the final step to assure that findings were not significant purely as a result of suppression effects of the covariates (Simmons, Nelson, & Simonsohn, 2011). In the case of a significant interaction, the nature of the effect was examined using post-hoc slope analyses as recommended by Aiken & West (1991).

Results

Independent samples t-tests demonstrated that individuals who engaged in the cycling group reported lower depression symptoms at treatment intake (M = 19.96, SD = 3.26) and discharge (M = 17.24, SD = 4.33) compared to those who did not cycle (M = 26.15, SD = 9.88; M = 21.14, SD = 12.14, respectively). There were no differences in age, intake or discharge PTSD symptoms, or sleep quality, between those who did and did not engage in the cycling group (*p's* range from .09 - .96). In terms of relations among key study variables, correlations demonstrated that intake sleep quality was positively associated with total PTSD symptom

severity and all individual symptom clusters at intake. However, exercise was unrelated to all factors, except for total number of days cycled (see Table 1).

Table 2 presents details of the four HMR analyses. In terms of total PTSD symptom severity, results revealed non-significant main effects and interaction. Regarding specific PTSD symptom clusters, results demonstrated that, while there was no main effect of exercise or sleep, an interaction emerged between exercise and sleep quality in relation to PTSD hyperarousal symptoms at discharge. This interaction remained significant after adjusting for age, hyperarousal symptoms at intake, change in depression symptoms, and total number of days cycled. Neither PTSD re-experiencing nor avoidance/numbing HMR analyses yielded significant interaction effects. Predicted values of hyperarousal symptoms as a function of exercise and sleep quality, modeled as poor sleep quality (+1 SD) and good sleep quality (-1 SD), are plotted in Figure 1. Exercise differentially impacted hyperarousal symptoms as a function of sleep quality. Specifically, slope analyses indicated that exercise was significantly related to lower discharge hyperarousal symptoms among those with relatively poor baseline sleep quality, β = -.24, p = .002, but not among those with relatively good baseline sleep quality, β = .09, p = .37.

Specificity Analyses

Specificity analyses were then conducted to determine if different exercise mileage (none, moderate, and high) resulted in differential relations between sleep quality, exercise, and discharge hyperarousal symptoms. Three separate HMRs were conducted as described above, however, the continuous index of exercise was replaced with a trichotomous (none, moderate, and high) index of exercise (see *Method* for a detailed description of how exercise was trichotomized). Results demonstrated that individuals who engaged in moderate, β = -.26, p = .03, or high, β = -.59, p = .01, mileage exercise and who had poor sleep quality reported the

lowest level of hyperarousal symptoms at discharge. This finding was not observed for individuals who did not exercise and had poor sleep quality, β = .07, p = .35. In addition, exercise group did not impact hyperarousal symptoms among individuals with good sleep quality. In relation to differences between exercise group, pairwise comparisons demonstrated that hyperarousal symptoms among the high mileage exercise group were significantly different from the non-exercise group, $M_{difference}$ = 1.87, p = .02, but not the moderate mileage exercise group, $M_{difference}$ = 1.77, p = .07. In addition the moderate mileage exercise group was not significantly different from the non-exercise group, $M_{difference}$ = 0.09, p = .90.

Discussion

The objective of the present study was to determine the effects of sleep and exercise (defined as miles cycled over the course of treatment) on PTSD symptom severity among U.S. military veterans engaged in residential PTSD treatment. Neither sleep nor exercise were directly associated with changes in total PTSD symptom severity or symptom clusters of re-experiencing or avoidance/numbing; however, sleep and exercise interacted to predict changes in PTSD hyperarousal symptoms. Exercise was associated with a significant reduction in hyperarousal symptoms from treatment intake to discharge among veterans with relatively poor sleep quality at intake. Conversely, among veterans with good sleep quality, exercise did not influence changes in hyperarousal symptoms. Results of specificity analyses suggested that hyperarousal symptoms at discharge significantly differed between the high mileage-and non-exercise groups, while no differences emerged between the high mileage and moderate mileage cycling groups or between the moderate mileage and non-exercise groups. This pattern of results suggests that exercise may function to reduce hyperarousal symptoms among individuals with poor intake sleep quality, with particular benefit to those who engage in higher mileage cycling.

Given that hyperarousal is a defining feature of PTSD and a key mechanism in insomnia, a condition that is highly comorbid with PTSD, exercise interventions may help further optimize treatment outcomes among population. This is particularly promising as exercise has been found to be an intervention that is highly acceptable among veteran populations, where engagement in treatment can often be a significant barrier (Buis et al., 2011).

This study is among the first to examine the combined impact of exercise and sleep in a clinical PTSD sample. Results are largely consistent with several areas of previous research regarding the relations between exercise, sleep, and anxiety more generally (Passos, Poyares, Santana, Garbuio, Tufik, & Mello, 2010; Zschucke, Gaudlitz, & Strohle, 2013). First, PTSD symptom severity (excluding sleep symptoms) was positively associated with poor sleep quality at intake, further highlighting the relation between sleep disruptions and recovery in this population (Germain, 2013). Second, as demonstrated by a wealth of previous studies on the impact of exercise on affective symptoms (See Zschucke, Gaudlitz, & Strohle, 2013), exercise was associated with improvements in PTSD symptoms, with results specifically supporting the conclusion that reductions in hyperarousal are one potential pathway through which these benefits are conferred. It is also noteworthy that these results were appreciable in chronic severe PTSD patients, a population that has proven resistant to both behavioral and pharmacological treatments, and over the course of a residential hospitalization, conditions conventionally viewed as reducing the detectability of individual treatment effects.

In addition, our findings provide an important first step for several areas of future research. To determine whether exercise improves PTSD outcomes via improvements in sleep, future studies should assess the extent to which exercise influences changes in sleep. Studies should also examine whether reductions in hyperarousal temporally mediate these relations.

Research identifying the mechanisms by which exercise may improve and/or sustain recovery outcomes will ultimately help clinicians tailor existing exercise interventions to better address the specific challenges faced by individuals with PTSD. Finally, research should examine the dose-response effect of exercise to determine if these relations vary as a function of frequency, intensity, duration, and type of exercise.

This study has important limitations. First, patients self-selected to participate in the biking program. Without random assignment, we cannot exclude the possibility that pre-treatment characteristics (e.g., motivation, self-efficacy) explain the observed improvements in hyperarousal symptoms despite the absence of pre-treatment differences on this criterion. Similarly, individuals were enrolled in treatment for varying amounts of time. While we controlled for the number of days cycled to account for increased opportunity to cycle, future research would benefit from standardizing opportunity to engage in the exercise intervention. Participation in the cycling program may have also increased engagement and participation in the program more broadly, leading to more symptom improvement. Second, it is plausible that time spent engaging with others in a social ("team") activity, and not exercise, per se, may have contributed to the observed improvements in symptom severity. These factors represent potential mechanisms through which exercise impacts PTSD symptoms and should be examined in future research. Third, limitations of the self-report sleep assessment were apparent in the relatively poor observed internal consistency. Future research would benefit from including objective sleep assessments (i.e., polysomnography, actigraphy). Fourth, our measure of exercise assessed total mileage cycled; therefore, conclusions cannot be drawn in relation to intensity/frequency of exercise. Future research would benefit from the inclusion of objective/physiological assessment to determine exercise frequency and intensity. Finally, the results should be replicated in an

outpatient setting where there is increased sample variability in PTSD symptom severity and where most PTSD patients receive their care.

In summary, the current study provides preliminary evidence for the potential utility of an adjunctive exercise intervention to improve recovery outcomes among veterans with PTSD who also struggle with sleep. Indeed, exercise represents a low-cost, patient-driven, non-medication-based, highly accessible intervention that does not require intensive professional training. Findings from this study provide preliminary support for the use of exercise interventions among veterans with PTSD and co-occurring sleep problems. Further empirical work focused on replicating and extending the present findings with more comprehensive assessments of exercise behavior and among other populations, including methods that may serve to increase exercise engagement (Irons, Pope, Pierce, Van Patten, & Jarvis, 2013), is needed.

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Table 1. *Correlations among Continuous Variables.*

	Variable	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1	Age	-	-	-	-	-	-	-	-	-	-	-	-	-
2	Δ Depression	-.02	-	-	-	-	-	-	-	-	-	-	-	-
3	Total Days	.02	.35**	-	-	-	-	-	-	-	-	-		
4	PTSD Total-I	-.06	.07	-.02	-	-	-	-	-	-	-	-		
5	Re-exp-I	-.07	.05	-.04	.84**	-	-	-	-	-	-	-		
6	Avoid-I	-.03	.03	-.00	.87**	.55**	-	-	-	-	-	-		
7	Hyper-I	-.06	.14**	-.03**	.80**	.55**	.59**	-	-	-	-	-		
8	PTSD Total-D	.03	-.46**	.02	.45**	.37**	.42**	.35**	-	-	-	-		
9	Re-exp-D	.02	-.37**	-.02	.48**	.50**	.38**	.32**	.86**	-	-	-		
10	Avoid-D	.06	-.44**	.02	.39**	.26*	.43**	.28**	.94**	.66**	-	-		
11	Hyper-D	-.01	-.42**	-.04	.38**	.28**	.33**	.39**	.89**	.67**	.79**	-		
12	Exercise	-.07	.00	.97**	.02	.01	-.00	.06	-.09	.01	-.12	-.12	-	
13	Sleep	-.10	.05	-.05	.27**	.21**	.23**	.23**	.02	.06	-.01	.00	.05	-
	Mean	52.18	4.51	1.16	62.02	18.04	27.87	16.10	57.20	17.91	24.74	14.55	30.17	15.55
	SD	7.06	11.21	4.88	9.41	4.39	4.62	2.72	12.85	4.28	6.52	3.70	113.23	3.66

Note: $n = 217$; * = $p < .05$; ** $p < .01$; Δ Depression = Change in depression symptoms from intake to discharge; Total Days = Total number of days cycled; I = Intake scores; D = Discharge scores; Re-exp = Re-experiencing symptoms; Avoid = Avoidance symptoms; Hyper = Hyperarousal symptoms; Sleep items were removed from the total PTSD symptom score and hyperarousal symptom cluster score; Exercise refers to miles cycled over the course of treatment; SD = Standard Deviation.

Table 2. *Results from HMR Analyses.*

		ΔR^2	*R*	*t*	*β*	*P*
DV: Total PTSD Symptom Severity						
Step1		0.01	0.09			
	Exercise			-1.39	-0.09	.16
	Sleep Quality-I			0.19	0.01	.85
Step 2		0.01	0.15			
	Exercise			-0.92	-0.06	.36
	Sleep Quality-I			0.29	0.02	.77
	Interaction			-1.64	-0.12	.10
Step 3		0.44**	0.68			
	Exercise			-0.37	-0.12	.75
	Sleep Quality-I			-1.25	-0.07	.21
	Interaction			-1.42	-0.08	.16
	Age			0.48	0.02	.63
	PTSD Total-I			7.65	0.41	.00**
	Change in Depression			-11.28	-0.58	.00**
	Total Days			0.12	0.05	.90
DV: PTSD Re-experiencing Symptoms						
Step 1		0.00	.05			
	Exercise			0.15	0.05	.49
	Sleep Quality-I			0.69	0.01	.88
Step 2		0.00	0.7			
	Exercise			0.35	0.02	.73
	Sleep Quality-I			0.73	0.05	.46
	Interaction			-0.80	-0.06	.42
Step 3		0.44**	0.67			
	Exercise			-0.71	-0.27	.48
	Sleep Quality-I			-0.54	-0.03	.59
	Interaction			-0.02	-0.00	.98
	Age			1.21	0.06	.22
	PTSD Re-experiencing-I			9.24	0.49	.00**
	Change in Depression			-9.24	-0.48	.00**
	Total Days			0.77	0.29	.44
DV: PTSD Avoidance/Numbing Symptoms						
Step 1		0.02	0.12			
	Exercise			-1.79	-0.12	.07
	Sleep Quality-I			-0.07	-0.01	.94
Step		0.01	0.15			

2						
	Exercise			-1.43	-0.10	.15
	Sleep Quality-I			0.00	0.00	.99
	Interaction			-1.16	-0.08	.24
Step 3		0.35**	0.61			
	Exercise			0.42	0.18	.67
	Sleep Quality-I			-0.99	-0.06	.32
	Interaction			-1.35	-0.08	.17
	Age			-0.57	-0.03	.56
	PTSD Avoid/Numb-I			6.07	0.35	.00**
	Change in Depression			-9.38	-0.32	.00**
	Total Days			-0.68	-0.28	.50
DV: PTSD Hyperarousal Symptoms						
Step 1		0.02	0.12			
	Exercise			-1.85	-0.13	.06
	Sleep Quality-I			-0.01	0.00	.97
Step 2		0.03**	0.22			
	Exercise			-1.10	-0.09	.21
	Sleep Quality-I			0.16	0.07	.35
	Interaction			-2.75	-0.19	.00**
Step 3		0.35**	0.63			
	Exercise			-0.73	-0.29	.46
	Sleep Quality-I			-1.10	-0.06	.27
	Interaction			-2.47	-0.15	.01*
	Age			1.06	0.06	.29
	PTSD Hyperarousal-I			6.78	0.38	.00**
	Change in Depression			-9.90	-0.54	.00**
	Total Days			0.48	0.19	.63

Note: n = 217; * = $p < .05$; ** $p \leq .01$; DV = Dependent Variable; Interaction = Sleep quality*Exercise; Sleep items were removed from the total PTSD symptom score and hyperarousal symptom cluster score; Total Days = Total number of days cycled.

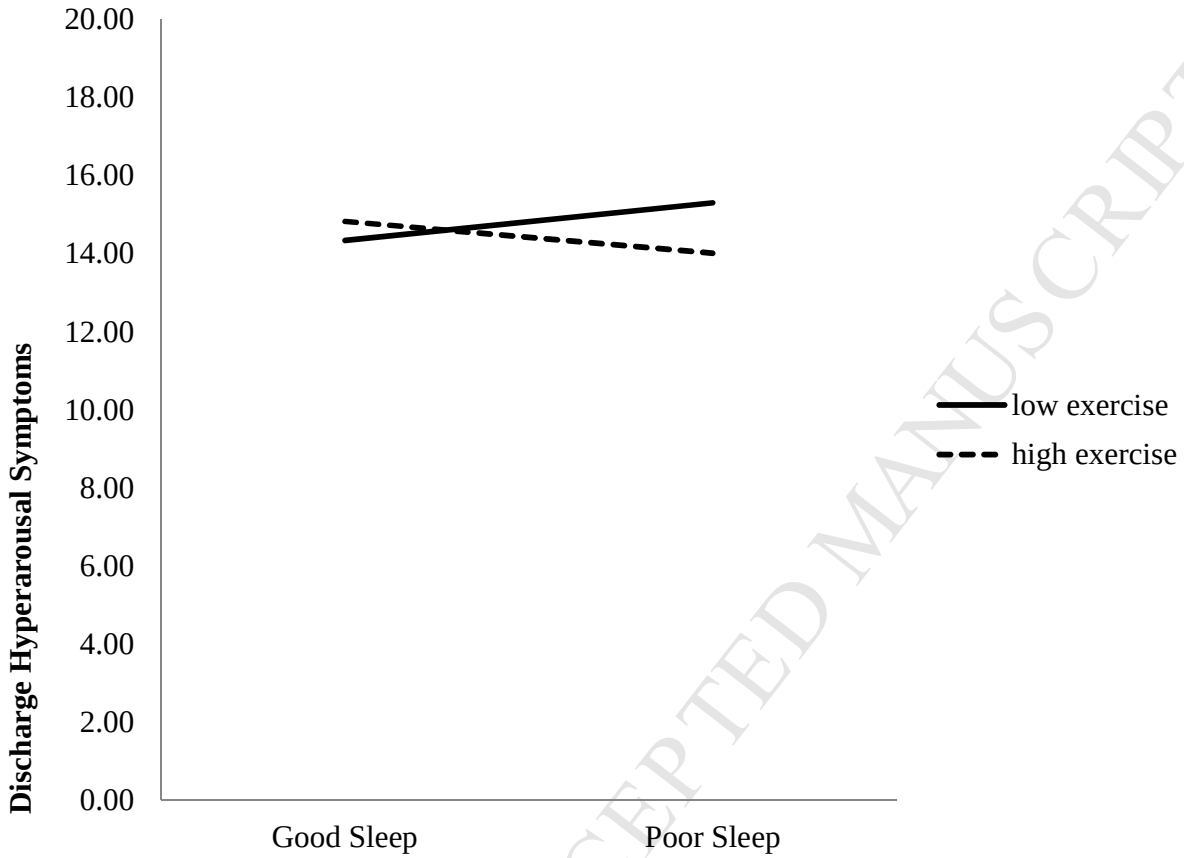

Figure Caption

Figure 1. The role of exercise on hyperarousal symptoms at discharge as a function of self-reported sleep quality. Low exercise refers to low mileage cycled, while high exercise refers to high mileage cycled, over the course of the intervention.

Highlights

1. Sleep and exercise interacted to predict changes in PTSD hyperarousal symptoms.

2. Exercise was associated with a significant reduction in hyperarousal symptoms from treatment intake to discharge among veterans with relatively poor sleep quality at intake.

3. Exercise may function to reduce hyperarousal symptoms among individuals with poor intake sleep quality, with particular benefit to those who engage in higher amounts of exercise.